GOES-R Precipitation Products

July 27, 2011

Presented By: Bob Kuligowski
NOAA/NESDIS/STAR

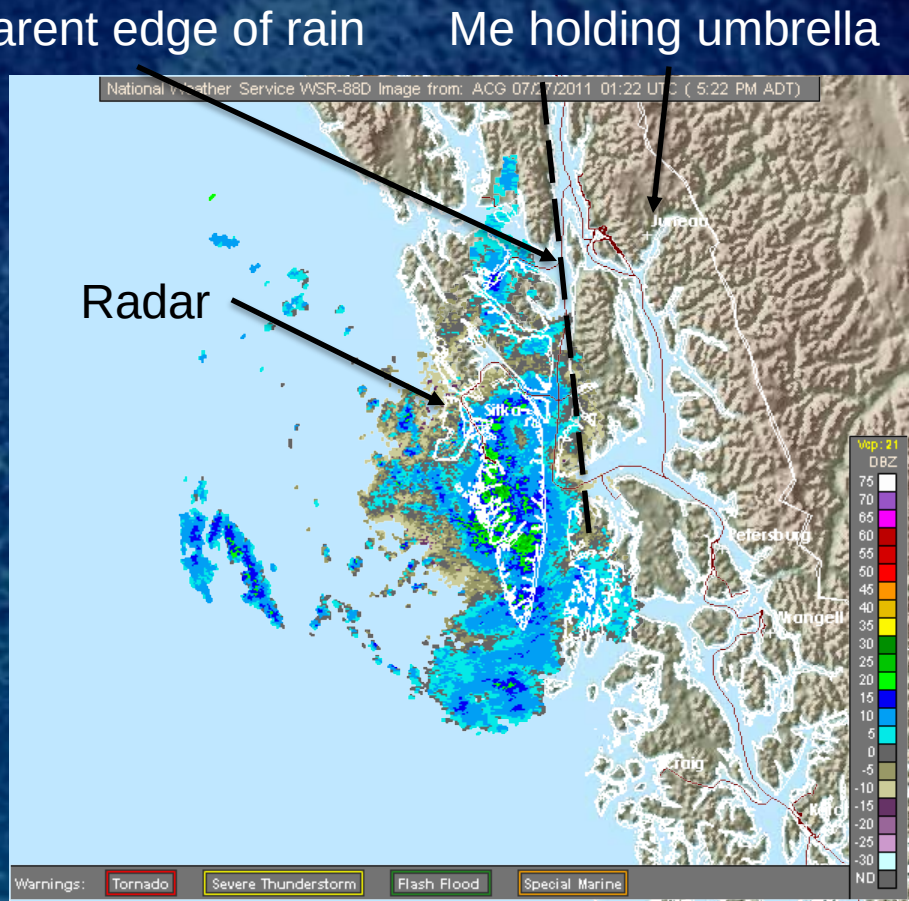
Thanks to: Richard Barnhill, Yaping Li, and Zhihua Zhang

Outline

- Background
  - » Motivation
  - » Satellite QPE Basics
- GOES-R Algorithms
  - » Rainfall Rate
  - » Rainfall Potential
  - » Probability of Rainfall
- Proving Ground Plans
- Summary

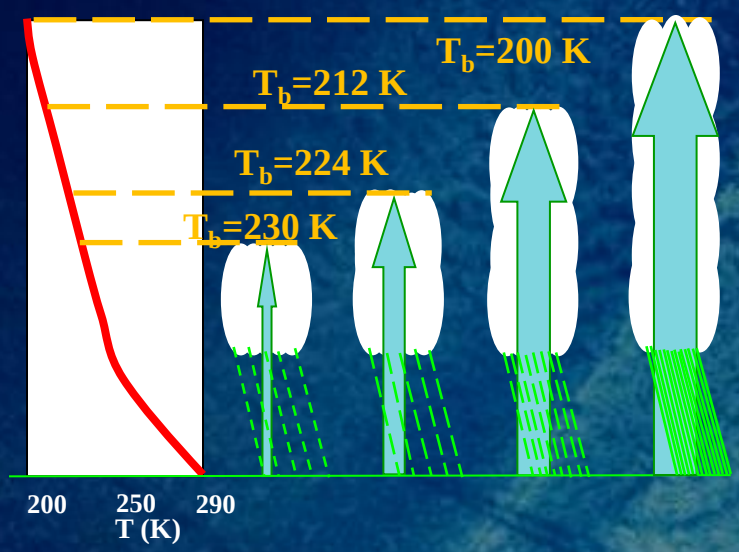
Motivation

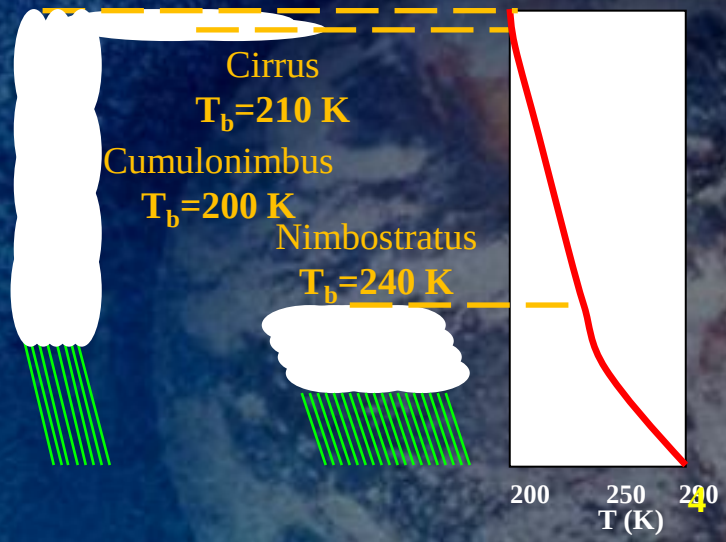
- Radar is highly valuable, but provides incomplete coverage due to
  - » Beam block
  - » Beam overshoot
  - » Radar unit placement
- This is particularly challenging in regions with complex terrain.



Satellite QPE Background: IR

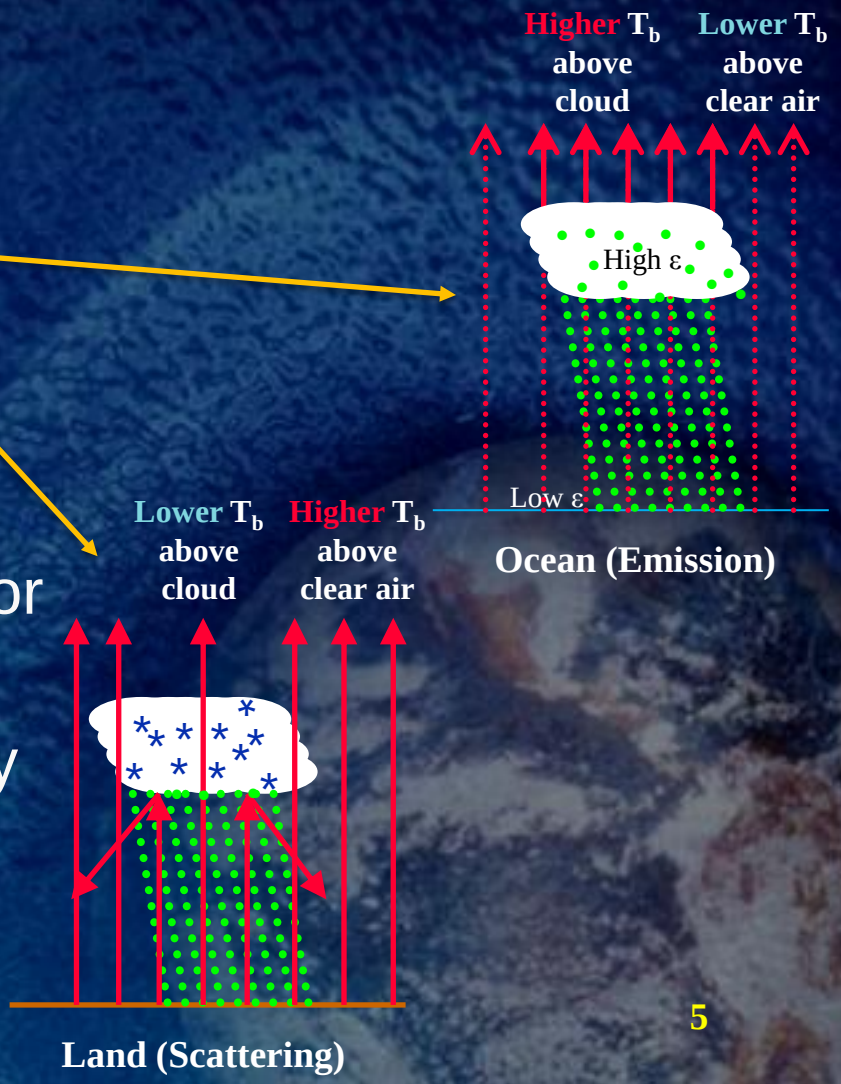
- IR-based algorithms retrieve rain rates based on cloud-top brightness temperatures:
  - » Cold tops→strong upward moisture flux→heavy rain
  - » Warm tops→weak / no upward moisture flux→light / no rain
- Works well for convective rainfall; poor assumption for stratiform rainfall





Satellite QPE Background: MW

- MW-based algorithms retrieve rain rates based on:
  - » Enhanced emission at low frequencies by cloud water
  - » Enhanced backscattering of upwelling radiation by cloud ice
- Emission over land only; significant detection problems for low-ice clouds over land
- Algorithms are calibrated mainly for the tropics (TRMM)



Other Satellite QPE Issues

- Primary interest is in rainfall rates at ground level; satellites detect cloud-top (IR) or cloud-level (MW) characteristics.
- Thus, no direct accounting for:
  - » Orographic effects
  - » Subcloud evaporation of hydrometeors
  - » Subcloud phase changes (e.g., snow to rain / sleet)
- Some algorithms (e.g., Hydro-Estimator) attempt to account for these effects using NWP model data

Implications for Satellite QPE Users

- Satellite rain rate estimates perform best for convective precipitation—about as well as radar ***without*** gauge correction
- Satellite rain rate estimates still perform very poorly for stratiform precipitation—in fact, NWP model forecasts are often more skillful than satellite QPE
- Satellite QPE has value, but users need to be aware of its limitations to maximize its usefulness

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Rainfall Rate Requirements

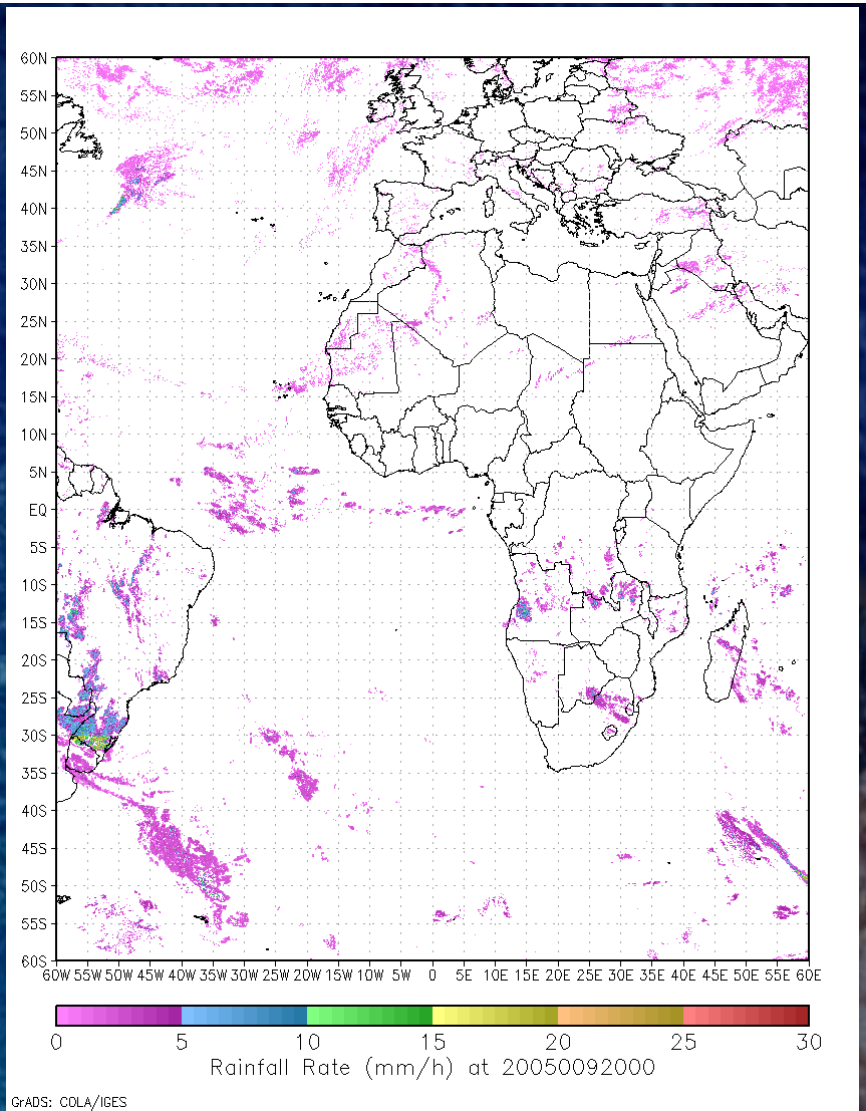
- Estimates of instantaneous rainfall rate…
  - …every 15 minutes
  - …at the full ABI pixel resolution (2 km at nadir)
  - …over the entire full disk
    - but with accuracy guaranteed only within 70º LZA and / or less than 60º latitude, whichever is less
  - …with an accuracy (bias) of 6 mm/h and a prevision (68th percentile of absolute error) of 9 mm/h, measured for pixels with a rain rate of 10 mm/h.

Rainfall Rate Description

- Microwave-derived rain rates are used to calibrate an algorithm based on IR data:
  - » MW-derived rain rates are the most accurate but not available continuously; only IR data can provide rapid refresh
  - » Objective: optimal calibration for a particular geographic area, cloud type, and season.
- Two calibration steps:
  - » Rain / no rain separation via discriminant analysis
  - » Rain rate retrieval via regression
- Calibration is updated whenever new MW data become available (older data are purged from the training data)
- The chosen channel set includes 5 ABI bands (6.19, 7.34, 8.5, 11.2, 12.3 μm) plus selected BTD's.

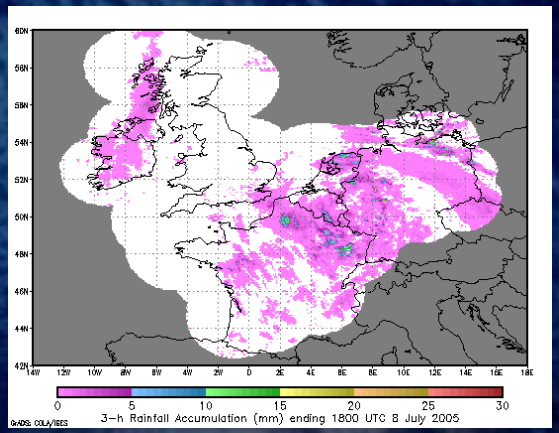
Example Rainfall Rate Output

- The GOES-R Rainfall Rate algorithm was developed using METEOSAT SEVIRI as a proxy; hence development and validation have been performed over Europe and Africa.
- Example retrieved from SEVIRI data on 9 January 2005.

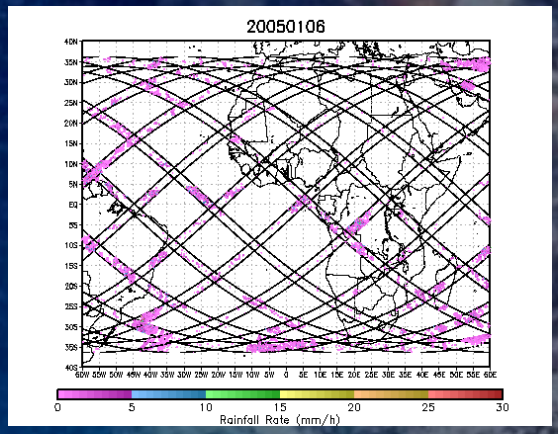


Rainfall Rate Validation

- Since the requirement is for instantaneous rain rates, radar is the only available source of data for validation against spec
- Ground-based radars:
  - » Nimrod radars in UK and Western Europe—5-km grid composite
- Space-borne radar:
  - » Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar
    - – Low-Earth orbit covers 35ºS-35ºN
    - – Swath width of ~250 km
    - – Surface footprint of ~3.1 km



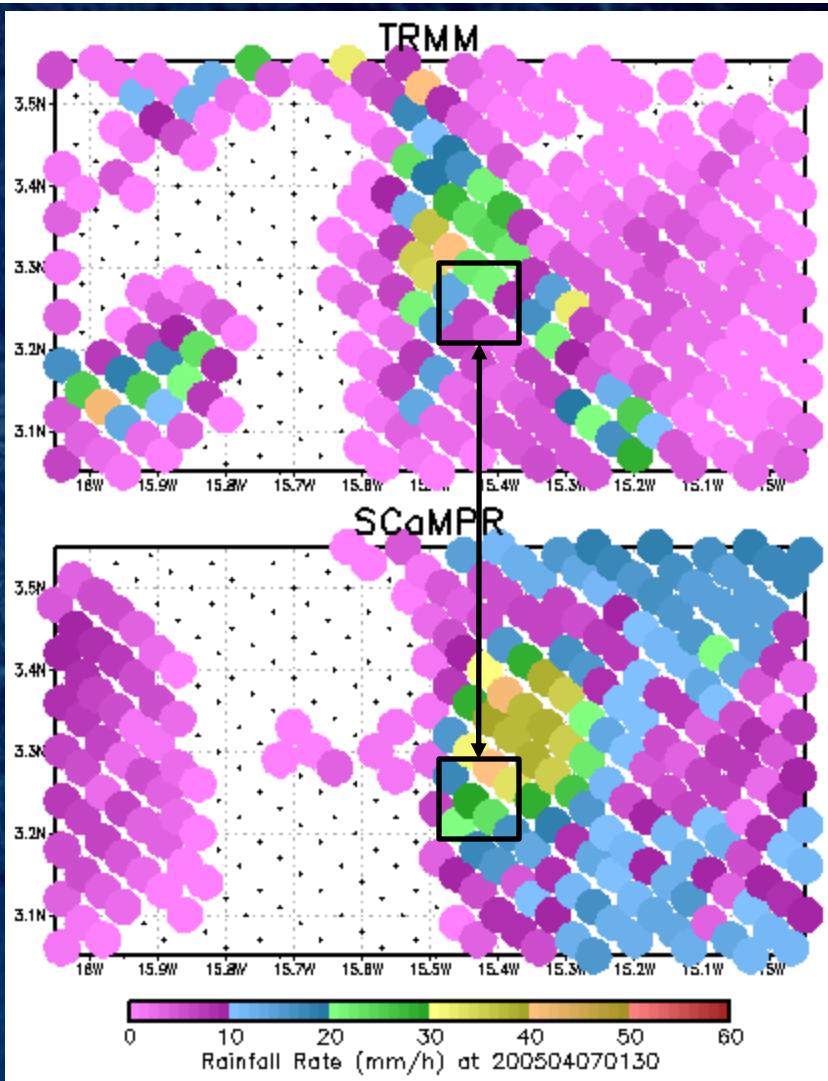
Sample Nimrod 3-h accumulation



Sample TRMM rain rates for a 24-h period

Rainfall Rate Validation

- High spatial variability of rainfall makes pixel-by-pixel comparisons extremely difficult
- Comparing with closest value in neighborhood instead of just the same pixel gives a better indication of usefulness
- A 15-km radius is used for Rainfall Rate validation against spec



Rainfall Rate Validation

Validation for 4 months of data (August 2006; February, April, and October 2007):

- Vs. collocated TRMM Precipitation Radar (±35ºlat only)

	F&PS (at 10 mm/h)		Evaluation vs. TRMM radar	
mm/h	Accuracy	Precision	Accuracy	Precision
Rain Rate	6.0	9.0	4.3	8.3

- Vs. Nimrod radar data (covering Western Europe only):

	F&PS (at 10 mm/h)		Evaluation vs. Nimrod radar	
mm/h	Accuracy	Precision	Accuracy	Precision
Rain Rate	6.0	9.0	7.7	9.6

Rainfall Rate Next Steps

- The Rainfall Rate algorithm was delivered to the GOES-R System Prime contractor in September 2012 and is "frozen" except for bug fixes.
- "Deep-dive" validation of the algorithm is ongoing and has revealed several potential improvements.
- Future versions of the algorithm may include
  - A separate calibration for warm (stratiform) clouds based on retrieved cloud properties (optical thickness and water path) from the ABI.
  - Adjustments for orographic effects
  - Adjustments for subcloud evaporation

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Rainfall Potential Requirements

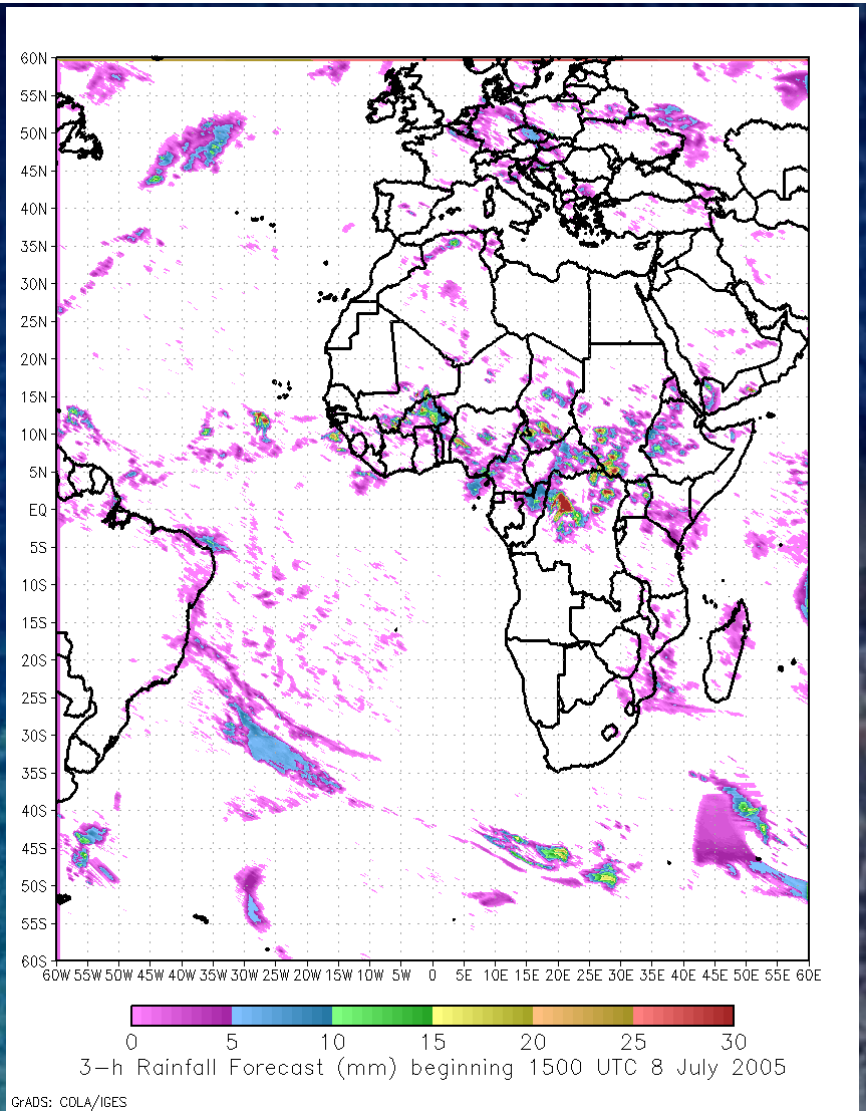
- Nowcasts of rainfall accumulation during the next 3 h…
  - …every 15 minutes
  - …at the full ABI pixel resolution (2 km at nadir)
  - …over the entire full disk
    - but with accuracy guaranteed only within 70º LZA and / or less than 60º latitude, whichever is less
  - …with an accuracy (bias) of 5 mm and a prevision (68th percentile of absolute error) of 5 mm, for pixels designated as raining.

Rainfall Potential Description

- The Rainfall Potential Algorithm is based on the NOAA / NSSL K-Means algorithm.
- Rainfall is extrapolated based on a comparison of current and previous Rainfall Rate imagery
  - » ONLY motion is extrapolated (no growth / decay)
  - » No initiation in an extrapolation-based approach
- Three basic algorithm components:
  - » Identify features in rain rate imagery
  - » Determine motion between features in consecutive images
  - » Apply motion vectors to create rainfall nowcasts

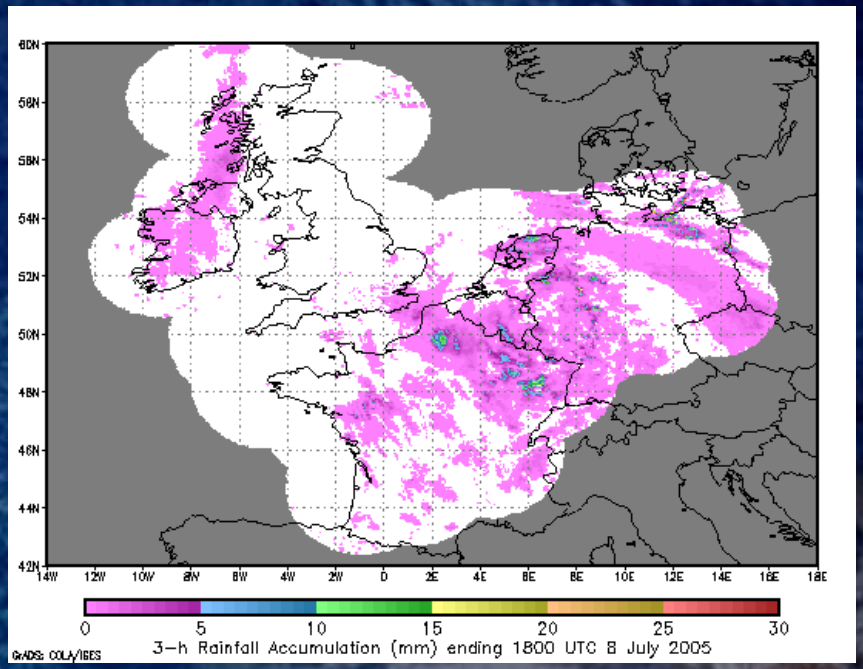
Example Rainfall Potential Output

Rainfall Potential from 1500-1800 UTC 8 July 2005 derived from Rainfall Rate fields (retrieved from SEVIRI data) at 1445 and 1500 UTC.



Rainfall Potential Validation

- Since the requirement is for rainfall accumulations of 3 h, radar and short-term gauges are the only available source of data for validation against spec
- Ground-based radars:
  - » Nimrod radars in UK and Western Europe—5-km grid composite



Sample Nimrod 3-h accumulation

Rainfall Potential Validation

Validation versus Nimrod radar data (covering Western Europe only) for 15 days of data: 6-9th of April, July, and October 2005:

	F&PS		Evaluation vs. Nimrod radar	
mm	Accuracy	Precision	Accuracy	Precision
Rainfall Potential	5.0	5.0	2.4	3.1

Rainfall Potential Next Steps

- The final GOES-R Rainfall Potential algorithm will be delivered in July 2012.
- Planned modifications of the current algorithm:
  - » Currently working on a method to account for intensity changes
  - » Investigating the use of information from the GOES-R Convective Initiation algorithm
- However, the Rainfall Potential algorithm is NOT slated for “Day-1” operational implementation due to funding issues.

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Probability of Rainfall Requirements

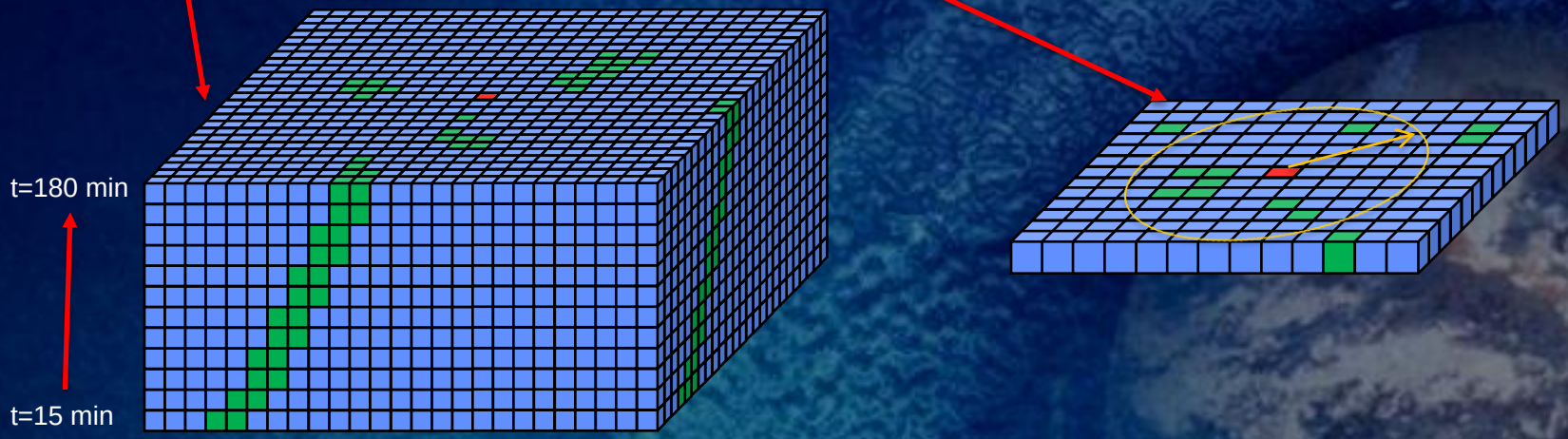
- Forecast of the probability of ≥1 mm of rainfall during the next 3 h…
  - » …every 15 minutes
  - » …at the full ABI pixel resolution (2 km at nadir)
  - » …over the entire full disk
    - – but with accuracy guaranteed only within 70º LZA and / or less than 60º latitude, whichever is less
  - » …with an accuracy (bias) of 25 percentage points and a prevision (68th percentile of absolute error) of 40 percentage points, for pixels designated as raining.

Probability of Rainfall Description

- The algorithm uses the intermediate (every 15 min) nowcasts of rainfall and 3-h accumulations from the Rainfall Potential algorithm as input.
- The algorithm was calibrated against the Rainfall Rate product instead of ground measurements to:
  - » Eliminate uncertainties associated with errors in the Rainfall Rate algorithm;
  - » Allow much more spatially widespread calibration (ground truth is generally available over Western Europe only)
- Calibration was based on the observed frequency of rainfall for each possible combination of 3 predictors (details on next slide).

Probability of Rainfall Description

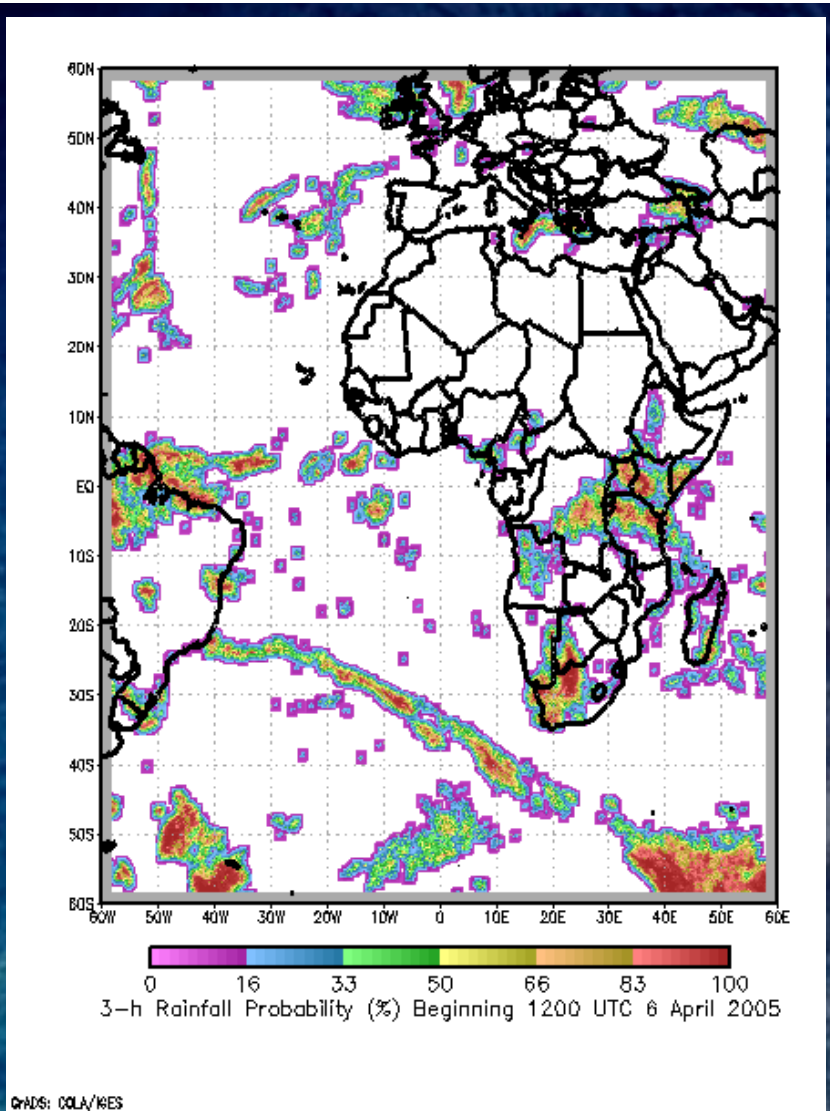
- The current predictor set consists of:
  - » 3-h rain accumulation at the pixel of interest
  - » Total number of instantaneous rain rates (15-180 min lead time) for all pixels within a 25x25-pixel area ≥ 1 mm/h
  - » Distance to nearest pixel (≤16 km) with 3-h accumulation ≥ 1 mm.



- Probabilities are retrieved from a lookup table (LUT) derived from the calibration data set.

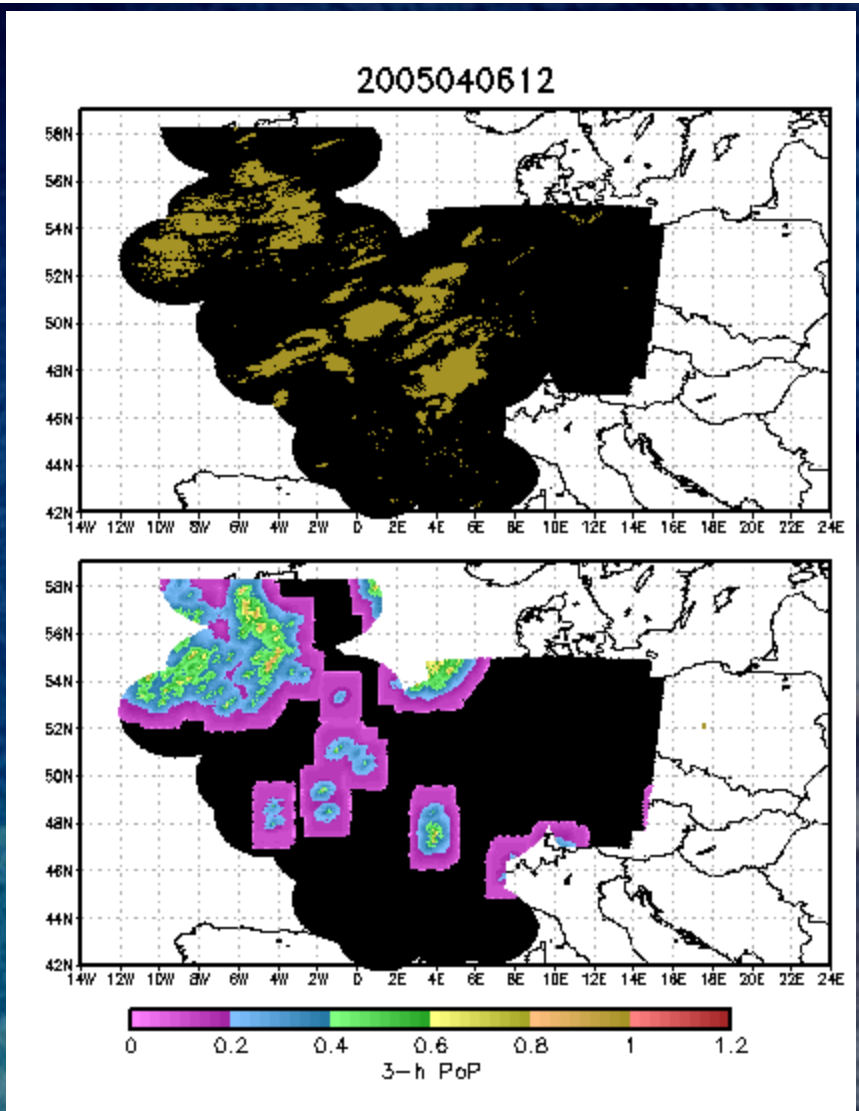
Example Probability of Rainfall Output

Probability of Rainfall from 1200-1500 UTC 6 April 2005 derived from SEVIRI data.



Example Probability of Rainfall Output

Comparison of Nimrod areas of ≥1 mm of rainfall from 1200-1500 UTC 6 April 2005 (top) with Probability of Rainfall from 1200-1500 UTC 6 April 2005 derived from SEVIRI data (bottom).



Probability of Rainfall Validation

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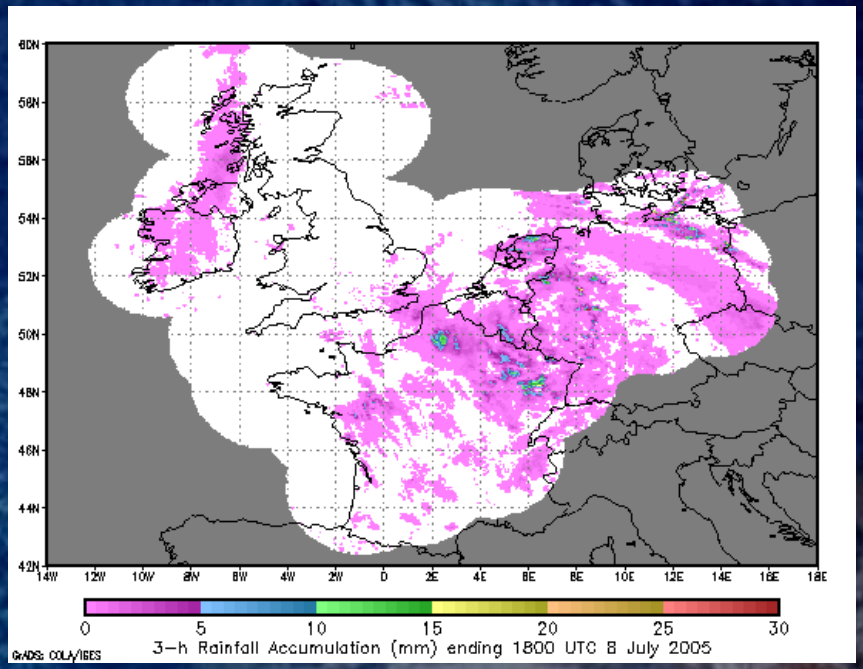

Sample Nimrod 3-h accumulation

Probability of Rainfall Validation

Algorithm validation versus Nimrod radar data (covering Western Europe only) for 15 days of data: 5th-9th of April, July, and October 2005:

	F&PS		Evaluation vs. Nimrod radar	
%	Accuracy	Precision	Accuracy	Precision
Probability of Rainfall	25	40	6	14

Probability of Rainfall Next Steps

- The final GOES-R Probability of Rainfall algorithm will be delivered in July 2012; additional predictors will be explored in the meantime.
- The calibration will be based on the final version of the Rainfall Potential algorithm.
- However, the Probability of Rainfall algorithm is NOT slated for “Day-1” operational implementation due to funding issues.

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Rainfall Rate

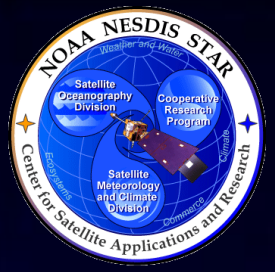
- Currently setting up a version of the GOES-R Rainfall Rate code that runs on the current-GOES channel set that will support the GOES-R Proving Ground exercise with HPC and SAB beginning in October 2011
  - » Some degradation of performance expected due to lack of 8.5-μm band (and soon 12.0-μm band) on current GOES
  - » Planned coverage for both GOES-W and -E, covering 165ºE – 15ºW and 60ºS – 60ºN
  - » Could extend farther north if significant interest (but the caveats from earlier in this talk need to be kept in mind…)

Rainfall Potential and Probability

- Once both algorithms are finalized in mid-2012, hope to set up both codes to run in real time at STAR if time and resources permit
- Initial plan is for same coverage area as Rainfall Rate, so coverage can be extended farther north if there is interest.

Summary

- QPE from satellites is best for convective rainfall, less skillful for stratiform rainfall
- Three precipitation-related GOES-R products:
  - » Rainfall Rate
  - » Rainfall Potential during the next 3 h
  - » Probability of Rainfall (at least 1 mm during the next 3 h)
- All products will be produced for the full disk every 15 min at the full ABI pixel resolution
- Only Rainfall Rate is slated for “Day-1” implementation
- A current-GOES version of the Rainfall Rate algorithm will be produced beginning this fall; the other two products may follow later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Questions?